Assignment #7

Name: ______________________________

Period: ______________________________

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Read the assigned article and answer the following questions on a *Google Doc*.

Your answers must be typed, double-spaced, no greater than size 12 font.

The information above (Name, period, date absent) must appear at the top of the page on your *Google Doc*, followed by answers to the questions below.

Effects of Plyometric Training on Sports Performance (Strength & Conditioning Journal, February 2016)

1. Give a general explanation of plyometric exercises. What are the intended effects for the athlete?
2. According to Carter, et. al., to what can performance enhancement be attributed?
3. How do the needs of tennis players, sprinters, and basketball players differ in regard to plyometric training?
4. What is the most studied performance measure in relation to plyometric training?
5. What do the authors assert about the apparent lack of effectiveness of plyometric training on the vertical jump performance of college-age females and highly trained male runners?
6. What kind of performance improvements are seen in field sport athletes as a result of plyometric training?
7. What kind of injury-prevention effects are most notable with plyometric training?
8. What effects are produced by doing plyometric training on different surfaces?
9. Based on the general conclusions of the authors, how could plyometric training benefit high school athletes?

Effects of Plyometric Training on Sports Performance

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ABSTRACT

PLYOMETRIC TRAINING IS A SERIES OF EXPLOSIVE BODY WEIGHT RESISTANCE EXERCISES USING THE STRETCH-SHORTENING CYCLE OF THE MUSCLE FIBER TO ENHANCE PHYSICAL CAPACITIES SUCH AS SPEED, STRENGTH, AND POWER. THESE PHYSIOLOGIC MEASURES TRANSLATE TO IMPROVED PERFORMANCE IN MANY SPORTS, INCLUDING COURT-BASED SPORTS, FIELD SPORTS, AND WATER SPORTS. PERFORMANCE ENHANCEMENTS RESULTING FROM PLYOMETRIC TRAINING, INCLUDE IMPROVED SPRINT TIMES OVER DISTANCES RANGING FROM 5 TO 40 M, MAXIMAL MUSCLE STRENGTH AND POWER, AND INJURY PREVENTION MEASURES SUCH AS IMPROVED LANDING MECHANICS, DECREASED GROUND REACTION FORCES, AND IMPROVED HAMSTRING TO QUADRICEPS RATIOS. THE OPTIMAL DOSE FOR ATHLETIC ENHANCEMENTS HAS NOT BEEN CONSISTENTLY IDENTIFIED.

INTRODUCTION

Plyometric training (PT) is a category of explosive body weight resistance exercises which focuses on exploiting the additional force output of the stretch reflex of a muscle to increase speed and power. A period of rapid concentric contraction in the muscle after a rapid eccentric lengthening of the muscle fiber under load enhances the force generated by the muscle. The stretch-shortening cycle (SSC) captures the energy of the stretched muscle in its elastic components and augments the next concentric contraction provided it is rapidly executed (73). This recoil effect can enhance physiological qualities indicative of improved sports performance (speed, strength, and power) when harnessed and trained correctly.

An array of field (3), court (30), and individual (2) sports use plyometric exercises. Correspondingly, the mode of exercises are wide and diverse ranging from double-leg, single-leg, in place, etc. (21,58,79). These exercises are not however limited to the lower extremities as upper body exercises (e.g., plyometric push-ups, chops, and medicine ball exercises) are commonly used for throwing sports (49).

PT is explosive in nature, therefore accurate measurement of performance is vital to detect significant worthwhile changes. It is measured in a number of ways. Most commonly, force plate measures (contact time, ground reaction forces, takeoff velocity) (12,15,22,77) and electromyography (16,22) to evaluate muscle activation patterns, are used to assess performance with plyometric exercise. Relative measures such as reactive strength indices (14) are also used when other methods are not possible, too expensive or impractical.

The purpose of this article is to review the existing literature on plyometric training and its training effects as they relate to a wide range of sports and their performance indicators. In doing so, it aims to provide practical guidelines for safe and effective programming within a variety of sports for performance enhancement and injury prevention programs.

PHYSIOLOGICAL ADAPTATIONS

PT elicits a variety of physiological adaptations, both structural and neural. Changes in muscle size and/or architecture are common (52), whereas reductions in fat mass are not usually seen (24). Traditional resistance training (RT) elicits similar training adaptations. Typically RT uses higher training volumes and allows for more concentrated eccentric loading. It therefore makes sense to combine RT and PT when programming for performance enhancement to maximize these training adaptations. Vissing et al. compared RT and PT programs over a 12-week period. They observed increased quadriceps, hamstring, and adductor whole-muscle cross-sectional area (CSA) by 7 and 10%, respectively, whereas total muscle size increased

KEY WORDS:
jump performance; strength; power; speed; explosive exercise

both with PT and RT (66). A study by Chelly et al. (7) found increases in thigh muscle volume were not accompanied by change in leg muscle volume and mean thigh CSA with PT.

More common structural changes relate to changes in the mechanical characteristics of the muscle-tendon complex and single-fiber mechanics (52). Increases in single muscle fiber diameters of 10% in type IIa, 11% in type I, and 15% in hybrid type IIa/x fibers have been reported (37). The most commonly examined area of structural change from PT involves analysis of the plantar flexor tendon responses such as stiffness (25,39,49,78), transmission of force (39), and CSA (39,45). Comparisons of these factors between traditional RT and PT have shown that changes in jump performance relate to changes in the MTC (71). However, Foure et al. observed no change in joint stiffness (18), whereas King et al. observed increased joint stiffness (31). This presents conflicting outcomes as a result of PT. Interestingly, Kubo et al. (33) attributed increased tendon stiffness to traditional RT but did not investigate the effects of PT. To date, no studies have compared the two types of training.

A study by Carter et al. found PT and isometric contraction interventions showed increased tendon stiffness in both groups where the difference in the extent of tendon stiffness changes accounted for 21% of the variance in performance improvement in jump height (4). These results are supported by a series of studies by Foure et al. investigating the effect of PT on the Achilles tendon complex (18–20). After 14 weeks PT, increases in tendon stiffness of 24.1% with no concurrent increase in tendon CSA indicated that these mechanical changes in the tendon were a qualitative rather than quantitative change. Any performance enhancement resulting from PT training may be due to improved force transmission (45) by a reduction in energy dissipation (18). The studies also suggested that the changes were limited to the Achilles tendon complex with no resultant changes in stiffness observed in the gastrocnemius tendon complex or ankle joint itself (19).

The gastrocnemius muscle did however exhibit changes in stiffness of 133% after 14 weeks PT training compared with the control group. The PT group demonstrated an improvement in squat jump (SJ) and reactive jumps of 117 and 119%, respectively (20).

The physiological adaptations of neuromuscular function to PT include increased neural drive to agonist muscles and changes in muscle activation strategies related to the SSC (39). Female, high school volleyball players recorded increases in peak hamstring torques (44% dominant side/21% non-dominant) and decreases in peak landing forces in conjunction with a corresponding 10% increase in vertical jump (VJ) height (25). In addition, Hewett et al. observed an increase in hamstring to quadriceps ratios peak muscle torque ratios of 26% dominant side, 13% non-dominant side. It is likely that these improvements in peak torque outputs relate to changes in landing kinematics. Specifically, changes have been observed in hip abduction/adduction and knee flexion angles (78). Both PT and balance training improved measures of lower extremity valgus during drop-jump landing where PT showed greater benefits for 2-foot landing tasks (45).

In the acute phase, PT demonstrates similar training-induced muscle damage responses as traditional RT (69). Excessive training volumes can induce neuromuscular impairments that can result in suboptimal training (13). Evidence suggests that PT causes damage to predominantly type II muscle fibers. Clearly distinguishable moderate and severe sarcomere damage in type II muscle fibers of both glycolytic and oxidative subtypes (86% and 84%, respectively, have been identified) compared with 27% in slow-twitch fibers (34). Elevated creatine kinase and lactate dehydrogenase levels (other measures of acute muscle damage) were reported 72 hours after PT with a concurrent increase in delayed onset muscle soreness over the first 48 hours after training (69). Immunological measures of muscle damage in the acute phase response have been mirrored along a similar timeline, by reduction in jumping performance (3,6) and rate of force development; thus providing evidence that acute responses are primarily a consequence of peripheral fatigue. Hence, adequate recovery between bouts of PT is imperative (13). By contrast, no differences in acute hormonal, metabolic, or neuromuscular responses to PT, regardless of repetition number, have been reported (2).

PLYOMETRIC TRAINING EFFECTS

PT can elicit varied training effects depending on the nature of the training program. This is usually determined by the desired sport-specific performance enhancement. For example, a tennis player would desire an improvement in agility. Greater enhancements in agility are seen using PT with a horizontal component (59). A sprinter may desire greater speed of foot strike which would also typically require some form of horizontal displacement in programming (72). Basketball or volleyball players, however, may require not only improved agility but greater vertical leap, which will require exercises with both horizontal and vertical components (31).

RUNNING ECONOMY

Maximal aerobic capacity is considered a key to running performance in distance events. However, other variables have been identified as better predictors of performance such as maximal aerobic velocity and running economy (46). Several studies have focussed on the benefits of PT to running economy for a wide variety of land-based sports. These include improved performance in middle and long distance runners. One study by Spurrs et al. noted a significant improvement (2.7%) in 3-km time trial for 17 male runners without concurrent improvement in maximal aerobic capacity ($\dot{V}O_2max$). This indicates the enhancements were due to muscular efficiency, not metabolic changes (64). Similarly, Vaczi et al. noted improvements in 18 male recreational runners in three separate running velocities after 6 weeks of PT. Averaged values ($m \cdot mL^{-1} \cdot kg^{-1}$) for the 3 running speeds were: (a) experimental subjects-5.14 ± 0.39 pretraining, 5.26 ± 0.39 posttraining; and (b) control subjects 5.10 ± 0.36 pretraining, 5.06 ± 0.36 posttraining. There was no concurrent improvement in $\dot{V}O_2max$ (71). Saunders et al. (61) investigated fifteen highly trained distance runners using three different running velocities (14, 16, 18 $km \cdot h^{-1}$) in 4-minute treadmill tests. They observed improvements in 18-$km \cdot h^{-1}$ test results after 9 weeks PT, without concurrent improvement in aerobic fitness.

MAXIMAL STRENGTH

Maximal strength is seen as a key performance indicator in most sports. Evidence suggests that this particular neuromuscular quality is an underlying factor in most areas of functional capacity (26,29,79). Research has demonstrated that PT has a positive impact on maximal strength and power (21). A meta-analysis by Saez-Saez de Villarreal et al. (58) of 15 studies on PT found a positive effect on lower-body maximal muscle strength. These strength gains have also been shown to be explosive in nature and enhanced by the addition of traditional RT (17,32). Greater improvements in maximal strength were observed in a combined RT/PT group (20%) when compared with a control group using PT only (6%) in 60 male physical education students (57). In addition to this, Ramirez-Campillo et al. (52) noted improved 5 repetition maximum squat strength in 29 middle-distance runners after 7 weeks of PT.

Marked improvement in maximal squat strength in college-aged males (35,41,57) and leg-press performance have also been reported (37,76). PT improved ballistic leg press by greater than 4-fold when compared with conventional RT (17–4% respectively) (76).

Another measure of strength, the hamstring to quadriceps (H:Q) ratio has been identified as a key indicator in anterior cruciate ligament (ACL) injury prevention. Young female recreational athletes showed an improvement in hamstring peak torques while maintaining quadriceps output after six weeks PT, therefore improving H:Q ratio and ACL injury risk prevention (70). Also, Malisoux et al. (37) showed individual fiber peak power outputs increased by 35% in type I, 25% in type IIa, and 57% in type IIa/IIx fibers.

SPRINT VELOCITY/AGILITY

A meta-analysis of 26 studies investigating the effects of PT on sprint performance found that sprint performance was optimized under the following parameters: (a) a training period of <10 weeks, (b) a minimum of 15 sessions in total, (c) high-intensity exercises, and (d) greater than 80 combined jumps per session (56). Furthermore, sprint-specific PT exercises such as those inclusive of an element of horizontal displacement were more beneficial than those without. Additional load in PT exercises was found to be ineffective as a method of overload. PT was shown to improve sprint performance over distances from 5 to 30 m in adolescents (5) and 40 m in junior soccer players (7,11). Improvements of 0.5–0.7 s have also been seen in agility trials, including 6 × 5 m shuttle run test, *t* Test, and Illinois agility test from pre- to post-test. There were no reductions in times for the control group in either measure (44). Despite the aforementioned improvements, PT has not been shown to be a better method of improvement in sprint performance than sprint training itself (52). This is in accordance with the theory of specificity in sports training. Thus, PT would be best used as an adjunct to specific sprint training to maximize speed and agility performance.

VERTICAL JUMP

The most studied performance measure in relation to PT is the VJ. The most commonly used plyometric exercises revolve around the VJ and variations of explosive jumping. Therefore, it is a common tool for both training and measurement of performance enhancement. A meta-analysis by Markovic of 26 studies of PT found improvements in depth jump (DJ) and SJ performance by 4.7% and countermovement jump (CMJ) performance by 8.7% (57). These findings are shown consistently in many studies of varying PT protocols. SJ has been observed to improve in adolescent boys over a 10-week program, consisting of 2 sessions per week, with training volume increasing from 60 to 100 jumps per session over the trial (32). Similar results have been seen in healthy untrained adult men training 4 days per week over 12 weeks (33). CMJ performance has been more widely documented. Improvements in the order of 7.5% and 10% have been reported in healthy adult male recreational athletes (17). Vissing et al. observed an increase of 10% in CMJ performance in untrained adult male subjects over a 12-week protocol training 3 days per week. Training volume increased from 60 impacts at the beginning to 180 impacts at the end of the study (76). Such improvements are not limited to bilateral CMJ. Untrained adult women improved single-leg CMJ performance and alternate-leg bounding after 12 weeks (3× per week) of PT (36). Not all studies, however, were unanimous in reporting improvements in VJ performance with PT. College-aged women (75) and highly-trained male runners (71) showed no improvement in VJ height which may indicate that 6 weeks of PT is insufficient to elicit performance gains in relation to jump height.

RELATIONSHIP TO SPORTS PERFORMANCE

COURT SPORTS

Athletes involved in court sports experience high levels of transfer of PT effects to sports performance. Basketball, volleyball, netball, handball, and tennis tend to require high levels of speed, agility, and jumping ability to perform tasks such as shooting in basketball and blocking in volleyball. Therefore, many studies have examined the effects of PT on performance. In a comparison of traditional PT and loaded plyometric exercise using weight vests in 27 elite male basketball players, both PT and loaded PT groups improved CMJ, SJ, and 5 repetition jumps performance with a significantly higher effect in the loaded group (30). Drop height was shown to play an integral role in the magnitude of gains with PT in 33 elite junior basketball players. The training protocol of DJ at a height of either 50 or 100 cm, three times per week for 6 weeks increased VJ height 4.8 cm and 5.6 cm, respectively (42). In a more comprehensive study of upper- and lower-body PT by Santos and Janeira (60) in 24 junior recreational basketball players, the intervention group significantly improved SJ, CMJ, DJ, and medicine ball throw performances after 10 weeks. A detraining effect, 6 weeks after training, was found when the PT stimulus was removed despite the continuation of regular basketball training.

VJ performance improved by +11.1% when compared with control +4% in 19 adolescent volleyball players with 6 weeks of aquatic PT (40) and in 22 male handball players +2.78% CMJ, 2.68% DJ, with a combined PT and sprint training protocol over 12 weeks (8). Tennis has also shown to benefit from PT. Tennis-related plyometric drills may be either upper- or lower-body in nature and benefit speed and agility components of the sport (59) and serve mechanics (23). In 26 elite junior tennis players, ball speed increased by 1–3% during a tennis serve when high volume upper-body PT was added to the traditional tennis warm-up before competition (23).

FIELD SPORTS

The transfer of PT effect to improvement in field sports performance relates more to improvement in sprint velocity and agility rather than jumping ability. This is probably due to the fact that these sports rarely involve jumping tasks during competition. Improvements in 10-m sprint time (−2.1%) and various agility tests (−9.6 %) have been observed in young athletes (43). Similar effects have been observed in elite men −0.29(s) (*t* test) and −0.26(s) (Illinois agility test) (74). The impact of PT on jump height and lower-extremity power and their relationship to kicking in soccer have also been explored. Of particular interest is the practical application to improved ball speed (48,63) or total kicking distance (55). In a study conducted by Rubley et al. (55) on 16 adolescent female soccer players, improvements were noted in VJ performance and kicking distance after 14 weeks PT, but not at seven weeks. This suggests young women may require longer adaptation periods than male soccer players.

PT in rugby players has primarily focussed on lower-body power outputs, speed, and agility. A study of under-19 university-level rugby players (n = 35) showed significant improvements in 20-m sprint time, Wingate anaerobic cycle test performance, and *t* test agility after 4 weeks of PT (50). A comparison of traditional postpotentiation activation strategies (i.e., heavy lifting stimulus before explosive activity) and PT showed that a set of 40 SJ produced an equivalent increase in CMJ performance to that seen in a heavy squat followed by CMJ test. Similar results were observed for tests timed at 1-, 3-, and 5-minute rest periods before CMJ (68). This research suggests a complex training protocol may not be required to elicit post-potentiation activation performance benefits.

THROWING SPORTS

The evidence suggests that upper-body plyometric exercises are a valuable tool in throwing sports for increasing upper-body power (62), and thus improving performance in track and field throwing athletes (47) and baseball pitchers (4). Significant improvement in concentric internal rotation and eccentric external rotation of the shoulder joint of division-1 baseball players (n = 24) after the ballistic-6 protocol (a set of 6 upper-body plyometric exercises) has implications for throwing velocity (4). The PT group improved throwing velocity from 83.15 to 85.15 mph after eight weeks of PT. Similar changes were not observed in the control group, making this an important performance enhancement for baseball.

WATER SPORTS

Several studies have examined the effects of PT in swimming, which may have sports-specific benefits for kicking propulsion and horizontal forces (9,53,54). Significant improvements in peak torques around both hip and knee joints were noted after 9 weeks of plyometric long jump training. The increased horizontal force (7%) and horizontal take-off velocity (16%) have significant performance implications for start times and tumble turns (51), swim performance time to 5.5 m (−0.59 seconds versus −0.21 for control group), and velocity of take-off to contact (0.19 milliseconds versus −0.07 milliseconds for control group) (2).

INJURY PREVENTION

Plyometric exercises are not only used for performance gain but as an injury prevention tool. PT has been shown to be more effective than RT in improving functional performance of athletes after lateral ankle sprain (28). When using PT in an injury prevention context, consideration must also be given to the type of exercise prescribed. Other considerations include the landing mechanics involved in lower-body exercises or rotational torques involved in upper-body exercises. Fundamental to landing mechanics are muscle recruitment strategies, joint angles, and loading patterns. Differences in hamstring and gluteal activities have been identified across plyometric exercises during the preparatory and landing phases. Single-leg sagittal plane hurdle hops produced the greatest gluteal and hamstring activity across both phases. This exercise may be important to include in ACL injury prevention programs (66). Investigation of seven plyometric exercises (2-foot ankle hop, repeated SJ, double-leg hop, DJ from 30 and 60 cm, and single- and double-leg tuck jumps) showed marked differences in mechanical output at the ankle and hip joints. Most variables at the ankle joint were greatest for two-foot ankle hop and tuck jumps, whereas most hip joint variables were greatest for repeated SJ or double-leg hop (67).

Table 1
Practical recommendations for implementation of plyometric exercises into sports specific training programs

	Training phase	Exercise modality	Duration	Frequency	Volume	Intensity	Rest	Combination
Court sports	Transition or precompetition	Unilateral and bilateral	>10 wk	2–3/wk	>50 contacts per session	High intensity loaded	3–4 min or 1:10	Electrostimulation
Field sports	Transition or precompetition	Unilateral and bilateral	<10 wk	Twice weekly	>80 contacts per session	High intensity loaded	1–2 min or 1:10	Conventional RT
Track and field	Competition or transition[a]	Unilateral and bilateral	<10 wk	Twice weekly	>80 contacts per session	High intensity loaded	4 min or 1:10	Olympic lifting[a]
Throwing sports	Competition or transition[a]	Unilateral and bilateral upper body	8–10 wk	Twice weekly	30–60 throws per session	High intensity loaded	1 min or 1:10	Olympic lifting[a]
Water sports	Competition or transition[a]	Horizontal displacement component	20 wk	3 times per week	>300 contacts per session	Low to moderate unloaded	2 min or 1:10	Olympic lifting[a]

RT = resistance training.

CONCLUSION

In conclusion, the length of PT programs, training dose (intensity, duration, and frequency of individual sessions), types of exercise, and placement in a periodized program will vary according to the sport, the training level of the athlete, the particular physiological attribute being trained (i.e., sprint performance, muscular strength, jump height), and the incorporation of other modes of RT. Precise volumes, frequencies, and intensities of PT have not yet been specifically elucidated for optimal improvements in sporting performance and further investigations are warranted. However, the findings of this review indicate that plyometric training can be a valuable tool to include into structured strength and conditioning programs to enhance sporting performance across a wide variety of land- and water-based sports.

PRACTICAL APPLICATIONS

When considering the practical application of PT, coaches should consider many aspects of the training program. Elements of programming such as program length, frequency of sessions, intensity of exercises, and volume are also crucial to the effects of PT and may differ depending on outcome measure. Bi-weekly sessions are recommended for most sporting categories, although water and court sports may require greater frequency. Performance enhancements are noted for programs less than 10 weeks in duration for most sporting categories. However, court and water sports seem to require longer training interventions. Recommendations from 2 meta-analyses into program length and frequency are contained in Table 1 (10,56). The intensity of exercises has been studied in relation to depth of drop jumps (1,38,42), unilateral versus bilateral exercises (36), and the addition of external loads (30). When considering box height for DJ, no consistent recommendations have been determined. Matavulj et al. (42) found that no differences in performance were gained from 50 cm or 100 cm heights. However, Marina et al. (38) conclude the optimal height for DJ to be between 40 and 60 cm. In terms of landing mechanics, bilateral differences in landing force and contact time are minimized from a height of 60 cm (1). When compared with bilateral plyometric exercises, unilateral PT produced power and jumping performance gains faster than bilateral PT, but performance gains are longer lasting after bilateral PT when the training stimulus is removed (38). The literature suggests high-intensity exercises and the addition of external load are beneficial for most categories except water sports. Low-intensity exercises have demonstrated the greatest benefit for this class of sports. Training volumes of higher than 50 foot contacts per session are suggested for court sports and 80 foot contacts are recommended for track and field sports. Throwing sports seem to require lower volumes of 30–60 throws per session. This may be due to the upper body nature of these exercises. Water sports require the highest training volume with greater than 300 contacts per session required to elicit a performance enhancement. Recommendations for exercise intensity and volume are contained in Table 1.

Plyometric exercise selection is another crucial element to consider. Programs aimed at enhancing performance must be designed differently from those that target reducing landing forces and minimizing injury risk (75). The exercises should be as specific to the tasks or skill set performed in the sport. For example, long jump training should be used instead of VJ to improve swim start performances (53). PT is considered to improve fitness characteristics that rely more on reactive strength and powerful leg push-off such as, lateral reaction time, 4 m lateral and forward sprints, drop jump and maximal force (59). Although sagittal plane, but not frontal plane, PT significantly improved VJ height in basketball players. Coaches should implement both types of PT as both contribute to improved power and speed (31).

One final consideration when programming PT is the nature of the surface on which the exercises are performed. Although traditionally performed on land-based surfaces (running tracks and grass fields), some studies have shown both aquatic and land-based PT produce improvements in VJ height (65). In addition, plyometric training on sand has shown improvements in both jumping and sprinting ability and induced less muscle soreness. A grass surface seems to be superior in enhancing CMJ performance, whereas the sand surfaces seem to elicit a greater improvement in SJ. Therefore, plyometric training on different surfaces may elicit different training-induced effects (27).

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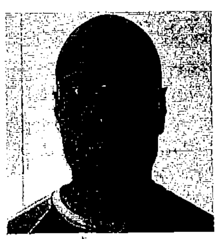

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REFERENCES

1. Ball NB, Stock CG, and Scurr JC. Bilateral contact ground reaction forces and contact times during plyometric drop jumping. *J Strength Cond Res* 24: 2762–2769, 2010.
2. Bishop DC, Smith RJ, Smith MF, and Rigby HE. Effect of plyometric training on swimming block start performance in adolescents. *J Strength Cond Res* 23: 2137–2143, 2009.
3. Cadore EL, Pinheiro E, Izquierdo M, Correa CS, Radaelli R, Martins JB, Lhullier FL, Laitano O, Cardoso M, and Pinto RS. Neuromuscular, hormonal, and metabolic responses to different plyometric training volumes in rugby players. *J Strength Cond Res* 27: 3001–3010, 2013.
4. Carter AB, Kaminski TW, Douex AT Jr, Knight CA, and Richards JG. Effects of high volume upper extremity plyometric training on throwing velocity and functional strength ratios of the shoulder rotators in collegiate baseball players. *J Strength Cond Res* 21: 208–215, 2007.
5. Chaouachi A, Hammami R, Kaabi S, Chamari K, Drinkwater EJ, and Behm DG. Olympic weightlifting and plyometric training with children provides similar or greater performance improvements than traditional resistance training. *J Strength Cond Res* 28: 1483–1496, 2014.
6. Chatzinikolaou A, Fatouros IG, Gourgoulis V, Avloniti A, Jamurtas AZ, Nikolaidis MG, Douroudos I, Michailidis Y, Beneka A, Malliou P, Tofas T, Georgiadis I, Mandalidis D, and Taxildaris K. Time course of changes in performance and inflammatory responses after acute plyometric exercise. *J Strength Cond Res* 24: 1389–1398, 2010.
7. Chelly MS, Ghenem MA, Abid K, Hermassi S, Tabka Z, and Shephard RJ. Effects of in-season short-term plyometric training program on leg power, jump- and sprint performance of soccer players. *J Strength Cond Res* 24: 2670–2676, 2010.
8. Cherif M, Said M, Chaatani S, Nejlaoui O, Gomri D, and Abdallah A. The effect of a combined high-intensity plyometric and speed training program on the running and jumping ability of male handball players. *Asian J Sports Med* 3: 21–28, 2012.
9. Cossor JM, Blanksby BA, and Elliott BC. The influence of plyometric training on the freestyle tumble turn. *J Sci Med Sport* 2: 106–116, 1999.
10. de Villarreal ES, Kellis E, Kraemer WJ, and Izquierdo M. Determining variables of plyometric training for improving vertical jump height performance: A meta-analysis. *J Strength Cond Res* 23: 495–506, 2009.
11. Diallo O, Dore E, Duche P, and Van Praagh E. Effects of plyometric training followed by a reduced training programme on physical performance in prepubescent